FAA HF-STD-008
8/8/2014

U.S. Department
of Transportation
Federal Aviation
Administration

U.S. Department of Transportation

Federal Aviation Administration

AIR TRAFFIC CONTROL TOWER ALERT STANDARD

F O R E W O R D

1. This standard is approved for use by all departments of the Federal Aviation Administration (FAA).

2. This standard establishes FAA requirements to apply when a new or modified system or subsystem with an alarm and alert component is designed, developed, or acquired.

3. Comments, suggestions, or questions on this document should be addressed to ANG-C1, 800 Independence Ave., SW, Washington, DC 20591, or emailed using the form under Contact Us at www.hf.faa.gov.

Table of Contents

1 Scope

This Standard provides design criteria and guidance for systems, subsystems and components involved in the presentation of alarm and alert signals to the Air Traffic Control Tower Operations environment. It is recognized that some of the design criteria provided herein may be applicable to other environments and workforces. However, the reader is cautioned to evaluate these criteria prior to their application in other areas.

This Standard specifies functional requirements, alarm and alert human interaction characteristics, and threshold levels that must be adhered to in the development of systems subsystems, equipment, assemblies, items, or parts that use an alert mechanism to capture human attention in the ATC environments specified.

1.1 Background

The FAA will acquire new tools and technology to improve their efficiency in the daily management of terminal air traffic systems of the National Airspace System (NAS). Current ATC systems are designed and manufactured by a variety of vendors who may implement alerts and alarms inconsistently (Ex.: completely different alarms for the same function). Inconsistent alert mechanisms increase controller stress and workload. Across ATC systems, alerts and alarms should have consistent functionality, meaning, and presentation modality/attributes. These alarms and alerts should minimize distraction, workload, and conflict demands. This standard will support system development and acquisition in the FAA Acquisition Management System (FAMS) by providing a means to better ensure that alarms and alerts meet consistent human factors design requirements for use in air traffic control systems and environments.

1.2 Purpose

The purpose of this standard is to provide an easy-to-use source of human factors alarm and alert design criteria oriented to support the mission and systems of the FAA Air Traffic Control Towers. By providing well-organized and clearly stated design criteria, this standard will facilitate both the development of effective, usable alarms and alerts and the achievement of the Agency's human-centered design goals.

1.3 Objectives

This section lists the objectives associated with the development of this standard. These objectives span many aspects of alarm and alert specification and development, and include:

a. Place relevant human factors, alarm and alert design information in a single, easy to use document.
b. Provide relevant alarm and alert design information that is based on research or accepted practices for use by FAA and contractor human factors professionals in new system acquisitions or modifications.

c. Provide human factors alarm and alert design information in the form of clear, concise, usable standards.
d. Organize the document so that users can easily locate the needed information.
e. Use credible and identified information sources.
f. Provide strong and comprehensive general alarm and alert design information.
g. Promote alarm and alert implementation consistency within and among new and modified/upgraded ATC tools, systems, and subsystems.
h. Serve as a basis for general human factors test and evaluation information and checklist procedures.

1.4 Applicability

This standard is intended for human factors practitioners, system designers, project managers and FAA program managers. It is intended to be applied whenever a new or modified system or subsystem that involves an alarm and alert component, is being designed, developed, or acquired. This standard applies when a developmental system, a Commercial-Off-The-Shelf (COTS) item, or a non-developmental item solution is selected. Although this standard will be applied on a system-by-system basis, the requirements and design criteria also apply if the entire alarm and alert system within a facility is redesigned.

1.5 Using this Document

The application of the standards in this document as requirements is not a guarantee of good design. Although this document focuses on achieving good design and consistency within and between systems, the standards within this document can be implemented in different ways. Standards provide a guide to good design, but standards cannot replace human factors expertise.

Thoughtful and measured use of this document in development and acquisition can lead to safer, more effective, more usable, and more efficient systems. However, even systems that are carefully designed using this document in conjunction with human factors experts will need to be verified through means such as prototyping and testing with representative users. Testing will allow the designer to confirm the positive design features, and identify negative design features that may have been missed by the standards and developers.

Finally, the use of this document is not a substitute for knowledge of task (user and system) requirements. The document user is assumed to have detailed knowledge of the system user and system operations.

1.5.1 Tailoring

Design requirements such as those contained in this document must be generally worded so that they can be applied to many different system applications. Before they can be applied to a specific system or piece of equipment however, these generally worded statements often need to be converted into system-specific rules. For example, a requirement that states that the options in a menu should be ordered in a way that minimizes user navigation may be rewritten for a specific system to specify the exact ordering of the items used for the system. This process is

known as tailoring and entails the process of selecting and evaluating individual standards to determine the extent to which they apply to a specific system or piece of equipment. It includes the process of modifying these standards to ensure that there is an optimal balance between operational needs and cost.

Tailoring of the standards may not always be possible. If the specifics of a system are not known in advance, a section of this standard may need to be cited in its entirety, with tailoring occurring later in the process.

Not every standard contained within this document will be applicable to every system. The application of every standard within this document to a single system would likely result in a system that is cost prohibitive. Tailoring the standards contained within this document to ensure applicability to a specific system avoids unnecessary effort and overly restrictive design, and can facilitate reduced cost.

Tailoring is the joint responsibility of human factors experts, vendors or system developers, users, and program managers. In order to tailor standards, the members of this working coalition must have a thorough understanding of task requirements and user characteristics. Each of these groups has something unique to contribute to the process. Users have knowledge of the task, people from the program office and vendors have knowledge of the costs involved in implementing recommendations, and human factors experts have knowledge of human capabilities and limitations relevant to the design of human-machine systems. Together, these representatives can determine which of the items will provide the most benefit overall.

As a first step in standards tailoring, a human factors practitioner must review the sections of this document to identify those standards that are relevant to the acquisition being considered. For a complex system or one with many components, the list of relevant standards may be extensive. Once all relevant standards have been identified on a general level, the standards should be reviewed to decide which specific ones are most appropriate for the particular system or equipment under consideration.

1.5.2 Use of *Must* and Should

As a standard, this document contains "best practice" recommendations as well as requirements. Accordingly, in this document, "***must***" statements indicate requirements. "Should" statements indicate "best practice" recommendations. The focus of this document is on requirement statements that are measureable and therefore enforceable. Consequently, every attempt has been made to minimize the use of "should" statements in order to make the document as easy to enforce as possible.

A "***must***" statement refers to a described, testable condition that must be met. "***Must***" statements specify requirements that originate from, or are comparable to, statements from authoritative sources such as those associated with FAA orders, standards, and military specifications. "Should" statements are recommendations that represent best practice information applicable in many situations. Either kind of statement may involve trade-offs, or may be influenced by context- specific factors.

1.5.3 Change Record

This is Release 1 of the Air Traffic Control Tower Alert Standard, dated August 8, 2014. It marks the first release following the efforts of the Alert Standard Working Group (ASWG) and their reviews, the adjudication of ASWG comments results from those reviews, and the adjudication of comments from an initial FAA review.

2 Applicable Documents

2.1 General

The documents listed in this section are referenced in sections 3, 4, or 5 of this standard. Sections 3, 4, and 5 specify additional reference standards to be applied when designing, building or testing alarms and alerts for FAA systems. Every effort has been made to ensure completeness of this standard, and document users are advised to apply the requirements of Sections 3, 4, and 5 for FAA Air Traffic Control Tower systems.

2.2 Government Documents

Citations listed in this section identify the documents used as references in this standard.

2.2.1 Specifications, standards, and handbooks

The following form a part of this document to the extent specified herein.

FEDERAL STANDARDS

Military

MIL-STD-1472G Design Criteria Standard – Human Engineering. 11 January 2012

(Copies of this document are available from
http://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=36903)

MIL-HDBK-1908B Definitions of Human Factors Terms. 16 August 1999

(Copies of this document are available from
http://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=121264)

Non-Military Federal Agency

FAA-HF-STD-001 Human Factors Design Standard. May 2003.

(Copies of this document are available from
https://www.hf.faa.gov/HFPortalNew/standards.aspx#gsc.tab=0)

2.2.2 Other government documents, drawings, and publications

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

Non-Military Federal Agency

NUREG-0700 Human-System Interface Design Review Guideline (revision 1, Volume 1). Washington, DC: United States Nuclear Regulatory Commission. 1996.

(Copies of this document are not available online.)

2.3 Non-government Publications

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ASTM F1166-07 Standard practice for human engineering design for marine systems, equipment, and facilities

(Copies of these documents are available from http://www.astm.org/Standards/F1166.htm.)

INTERNATIONAL ELECTROTECHNICAL COMMISSION (IEC)

IEC 6172,1-2004 Electroacoustics - Sound Level Meters – Specifications. 2004.

(Copies of this document are available from http://webstore.iec.ch)

NATIONAL AIR TRAFFIC SERVICES

No Identifier Human Factors Guidelines Database. Christchurch, UK: National Air Traffic Services, Human Factors Unit. 1999.

(Copies of this document are not available online.)

2.4 Order of Precedence

In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Requirements in this document do not, however, supersede applicable laws and regulations unless a specific exemption has been obtained.

3 Definitions

Absolute identification. Refers to the situation where the specific nature and identity of a given signal must be immediately recognizable in various contexts and unambiguous.

Acknowledged. An alarm or alert is acknowledged when the operator has made some type of input (such as pressing a button) to indicate receipt of the alarm or alert message provided by the system. The act of acknowledging an alarm or alert typically causes the attention-getting characteristics to cease.

Alarm. An alarm is a signal that indicates that the value of a monitored parameter, component, system, or function is outside the specified acceptable range, and immediate action is required to prevent loss of life, equipment damage, or disruption of National Airspace System (NAS) operations.

Alarm and alert availability. Alarm and alert availability refers to the means by which the results of alarm and alert processing are made available to the operators. Three typical availability techniques are filtering, suppression, and prioritization.

Alarm and alert display. An alarm and alert display refers to the presentation of alarm and alert coding and messages to the operators.

Alarm and alert message. An alarm and alert message is the information presented to the operator by the auditory, visual, and other display devices of the system in response to an alarm or alert condition.

Alarm and alert signal processing. Alarm and alert signal processing refers to operations performed on the signals by the system for evaluation. This process, which includes signal validation and other techniques, determines whether an alarm or alert condition exists.

Alarm and alert system. An alarm and alert system is a system consisting of processing hardware, display hardware, and display software, which processes or analyzes signals from sensors and informs the operator (via visual and/or auditory displays) when monitored parameters deviate from specified limits (setpoints) or predefined conditions.

Alarm and alert processing techniques. Alarm and alert processing techniques are the rules or algorithms that are used to analyze sensor data to determine their importance, validity, and relevance, and to determine whether an alarm or alert message should be presented to the operator.

Alert. An alert is a signal that indicates the existence of a condition requiring immediate attention but not immediate action. An alert signal indicates that an operational status or a condition status of an infrastructure resource has degraded or failed, or the resource functions may degrade or fail if action is not taken as soon as practicable.

Alert hierarchy. Alert hierarchy refers to the discrete hierarchy of increasing response urgency implied when using information signals for advisories, alert signals for cautions, and alarm signals for warnings.

Alphanumeric codes. Alphanumeric codes refer to the use of letters or numbers to represent information.

Audio signal. An audio signal is a signal that is heard rather than seen or felt.

Auditory icon. An auditory icon is a nonverbal, familiar, everyday sound that intuitively conveys information about an object, for example, using a siren sound to represent an emergency vehicle; earcon.

Coding. Coding is a system of assigning meanings to symbols, letters, colors, or symbol characteristics to represent information. In general, coding is used to differentiate items of information; to attract a user's attention to important information; to attract a user's attention to unusual situations or potential problems; or to indicate changes in the state of a system. Coding can also be used to differentiate categories of data. When used effectively, coding can decrease visual search time – thus permitting the Tower Operations (TO) specialists to monitor and control systems of the NAS in a safer and more effective manner.

Conflict alert. A conflict alert is a function of certain Air Traffic Control automated systems that is designed to alert the radar controller to existing or pending situations between tracked targets (known IFR or VFR aircraft), and requires his/her immediate attention.

Contrast ratio. For this standard, contrast ratio is defined as Lmax / Lmin, where Lmax is the greater of two luminances being compared and Lmin is the lesser, expressed as a ratio, e.g., 2:1

Core commands. Core commands are commands that are common across systems, i.e., such as a conflict alert.

Decibel (dB). A decibel is a unit for expressing the ratio between two levels of a physical quantity. In this standard the reference physical quantity is acoustic power, measuring the comparative sound pressure levels of sounds. One decibel (0.1 bel) equals 10 times the common logarithm of the power ratio; that is, doubling the intensity of a sound means an increase of a little more than three decibel (3 dB).

Decibel (dBA). A dBA is a sound level in decibels, measured using A-weighting. The use of A-weighting is applied to instrument-measured sound levels to account for the relative loudness perceived by the human ear. (The human ear is more sensitive to high frequencies and less sensitive to low frequencies and A-weighting refers to a curve defined in IEC 61672-2004 that makes accommodation for this bias in instrumented measurements of sound levels, such as with a sound level meter. A-weighted measurements correlate well with measures of speech interference and judgments of loudness).

Design eye position. The “design eye position” is the midpoint of the “design eye line” from which all workstation dimensions are related and referenced.

Earcon. An earcon is a simple, nonverbal sound arbitrarily assigned to represent an object; the auditory analogue of a visual or graphic icon; auditory icon.

Event. An event is any occurrence that may be significant. Specialists need to have specific types of events coded, such as alarms and alerts generated by various systems or identified by specialists.

False alarm or alert. A false alarm or alert is the presentation of a signal indicating an out-of-tolerance condition when, in fact, an out-of-tolerance condition does not exist.

Filtering. Filtering is a processing technique by which irrelevant, less important, or otherwise unnecessary alarms and alerts are eliminated. These messages are not available to the specialists. This is in contrast to suppression, which does not make the messages immediately available but does allow the specialist to retrieve them.

Flag. A flag is a visual mechanical or electromechanical device used to show a change in the status of an indicator, instrument, or its associated system.

Highlighting. Highlighting is a means of directing the user's attention to a feature of the display. Highlighting methods include image reversal (reverse video), brightness contrast, color, underlining, blinking, flashing arrows, and changes in font.

Icon. An icon is a pictorial, pictographic, or other nonverbal representation of objects or actions.

Information signal. An information signal indicates a safe or normal configuration, a condition of performance or operation of equipment, or it attracts attention and imparts information for routine action purposes.

Integrated display. An integrated display is a display that can operate in several modes or functions, one of which is the presentation of alarm and alert signals.

Master alarm signal. A master alarm signal is a visual signal that indicates that one or more alarm signals have been energized.

Master alert signal. A master alert signal is a visual signal that indicates that one or more alert signals have been energized.

Monitor alarm value. A monitor alarm value is an important parameter that is monitored by a shutdown function, and has standard values with tolerances or limits around that defined value.

Normal. Normal indicates that a system is operating within its ideal operating range and no action is required.

Nuisance alarm or alert. A nuisance alarm or alert is the presentation of an alarm or alert signal that indicates a non-critical condition or situation; the condition or situation is not operationally relevant and does not require any action from the user. An example is an alarm that monitors temperature that activates when the temperature is on the threshold of changing. This alarm is continually activated but no user action is required because temperature is controlled by a thermostat.

Operational significance override. This refers to the subordination of the presentation of signals of lesser operational significance to those of higher operational significance.

Peak Clipping. The use of electronic filtering techniques to eliminate high-amplitude speech signal components with minimal loss of intelligibility.

Pre-alarm value. A pre-alarm value is a parameter that has an alarm set to provide an indication that it is approaching an out-of-tolerance condition.

Prioritization. Prioritization is a processing technique that presents alarm and alert messages to the operator according to an evaluation of importance, often using categories of priority. The intent of this approach is to help the operators focus attention on the most important alarm and alert conditions when there are multiple alarms and alerts.

Relative identification. Refers to the situation or condition in which a given signal's message is context dependent, in other words, its value is interpreted relative to other signals.

Setpoint. A setpoint is the value of a monitored parameter that defines the boundary between the parameter's normal range and an alarm or alert condition. An alarm or alert condition exists when the parameter exceeds the normal range that is defined by the upper and/or lower limit setpoints.

Signal validation. Signal validation is a processing technique by which signals from redundant or functionally related sensors are compared and analyzed to determine whether a true alarm or alert condition exists. The purpose is to prevent false alarms and alerts from being presented to the operator due to malfunctioning instrumentation, such as a failed sensor.

Sound localization. Sound localization is a listener's ability to identify the location or origin of a detected sound in distance and direction.

Speech interference level. Speech interference level is a measure of the effectiveness of noise in masking speech. It is the arithmetic mean of the same pressure levels of interfering noise (in dB) in the four octave bands centered on the frequencies 500, 1,000, 2,000, and 4,000 Hz, respectively. The unit of speech interference is the decibel (i.e., dB).

Suppression. Suppression is a processing technique by which alarms and alerts that are determined to be less important, irrelevant, or otherwise unnecessary are unavailable to the specialists, but can be accessed upon request. This is in contrast to filtering, which does not make the messages available.

Symbol coding. Symbol coding is the use of visual symbols or icons to represent status information to the user.

Tactile signal. A tactile signal is a signal that is felt rather than seen or heard.

Timbre. Timbre is the quality of a sound determined primarily by the fundamental frequency and harmonics it contains and, to a lesser extent, by its amplitude envelope.

Tone. A tone is a sound with definable regularity of oscillation or no oscillation (steady tone).

Unacknowledged. An unacknowledged alarm or alert is an alarm or alert that has not been acknowledged and displays attention-directing characteristics, such as rapid flashing.

Unambiguous. As the term relates to signals and their presentation, signal intent must be unambiguous to one trained in the field of ATC operations.

Unmonitored/inactive. An unmonitored/inactive system is a system that is not monitored, directed, or controlled. This is a status imposed on the system by the user. A system may be unmonitored, unmanaged, or inactive because (a) it is awaiting a maintenance action; (b) it is not a system that is currently used; or (c) it is being used for training or similar reasons. Specialists may still need to see the status of individual components.

Visual angle. A visual angle is a measure (in degrees) of the size of the retinal image subtended by a viewed object. It represents the apparent size of an object based on the relationship between an object's distance from the viewer and its size (perpendicular to the viewer's line of sight). An object of constant size will subtend a smaller visual angle as it is moved farther from the viewer. Visual angle is typically defined in terms of minutes of visual arc.

Visual signal. A visual signal is a signal that is seen rather than heard or felt.

Voice signal or message. A voice signal or message is an audio signal with a verbal communication format.

4 General Requirements

This section covers general requirements that are applicable to alarm and alert components and their implementation.

4.1 System requirements

This subsection covers general requirements applicable to alarm and alert components and their implementations for the Tower Cab environment.

4.1.1 Design attributes.

An alarm and alert system ***must*** be designed with the following objectives and characteristics.

4.1.1.1 Signal abnormal operation

An alarm and alert system *must* provide audible or visible alarms or alerts only when systems are operating abnormally or other than normal conditions, as specified in the operating manuals.

4.1.1.2 Reduce operator demands.

An alarm and alert system ***must*** reduce operator assimilation and memory demands.

4.1.1.3 Minimize response time.

An alarm and alert system ***must*** minimize the time required for the operator to detect and assess the situation and to initiate corrective action(s).

4.1.1.4 Detectable and understandable signals.

An alarm and alert system ***must*** provide audible and/or visual signals that can be easily detected and understood.

4.1.1.5 Maximize ease of recognition.

An alarm and alert system ***must*** be standardized to maximize ease of recognition.

4.1.1.6 Allow for system growth.

An alarm and alert system ***must*** allow for system growth without requiring the addition of system components (such as might be accomplished by achieving system growth in capability with a software upgrade).

4.1.1.7 Alert user to existing problem.

An alarm and alert system ***must*** alert the user to the fact that a problem exists.

4.1.1.8 Inform the user.
An alarm and alert system ***must*** inform the user of the priority and nature of the problem.

4.1.1.9 Guide initial responses.
An alarm and alert system ***must*** guide the operator's initial responses.

4.1.1.10 Highlight disturbances.
An alarm and alert system ***must*** alert and guide operators to a disturbance.

4.1.1.11 Highlight out-of-tolerance variables.
An alarm and alert system ***must*** help operators locate out-of-tolerance variables, such as with the use of pre-alarm values to provide indication that a parameter is approaching an out-of-tolerance condition.

4.1.1.12 Highlight abnormal changes in system state.
An alarm and alert system ***must*** display out-of-tolerance changes in system states.

4.1.1.13 Prod user to action.
An alarm and alert system ***must s***tir or prod the operators to attention or action.

4.1.1.14 Set context.
An alarm and alert system ***must*** change the operators' mental state to facilitate the appropriate decision.

4.1.2 Purpose.
If equipment is not regularly monitored, an audio signal ***must*** be provided to indicate malfunctions or conditions that would cause injury to personnel, an impact on the NAS operations, or equipment damage.

4.1.3 Level (alarm, alert, or information).
Conditions that fall into the alarm or alert category ***must*** be based on the particular system or subsystem, the impact on the NAS, the likelihood of personal injury, the likelihood of equipment damage, and the operator's information requirements.

4.1.4 Performance.

4.1.4.1 Human perceptual and cognitive limits.
The alarm and alert system ***must*** be explicitly designed to take account of human capabilities and limitations, so that unacceptable demands are not placed on users by exceeding their perceptual and cognitive abilities.

4.1.4.2 Condition detection.
An alarm and alert system or signal ***must*** provide the user with a greater probability of detecting the triggering condition than his or her normal observation would provide in the absence of the system or signal.

4.1.4.3 Timely notice.
Alarm and alert setpoints ***must*** be determined to ensure that the operator can monitor and respond to out-of-tolerance conditions in a timely manner.

4.1.4.4 Action facilitation.
Each alarm or alert should prompt user action. If no action is required, then that message should not be conveyed via an alarm or alert.

4.1.5 Training.
Training techniques should be devised to ensure that users are exposed to all forms of the alarm and alert hierarchy, i.e., alarm, alert and information signals, as well as possible combinations of alarms, alerts and information signals, and that they understand how to deal with them.

4.1.6 Accessibility/ operability.

4.1.6.1 Line-of-sight (LOS).
Visual alarm and alert indications ***must*** be located within 60 degrees on either side of the line of sight of the operator's normal working position.

4.1.6.2 Access to controls and displays.
Visual alarm and alert displays should be located near the controls and displays that are required for corrective or diagnostic action in response to the alarm or alert.

4.1.6.3 Distinct coding of controls.
Alarm and alert system controls ***must*** be distinctively coded for easy recognition.

4.1.6.4 Consistent layout.
Each set of alarm and alert subsystem controls should have the functions in the same relative locations.

4.1.6.5 Separate controls.
Separate controls ***must*** be provided for silence, acknowledgment, and testing.

4.1.6.6 Disabling controls.
Alarm and alert system control design ***must*** not allow controls to be altered or disabled.

4.2 Signal requirements.

4.2.1 Modality.
The alarm or alert signal ***must*** be presented by the most effective modality (aural, visual, tactile) taking into consideration the user's tasks and the particular operating environment.

4.2.2 Signal characteristics.

4.2.2.1 Inform user of problems.
When appropriate, the signal ***must*** inform user that a problem exists.

4.2.2.2 Relay priority and nature.
As appropriate, the signal ***must*** inform the user of the priority and nature of the problem.

4.2.2.3 Guide initial response.
When appropriate the signal ***must*** guide the user's initial response.

4.2.2.4 Confirm response.
An appropriate signal ***must*** confirm in a timely manner, whether or not the user's response corrected the problem.

4.2.3 Signal clarity.
Alarm and alert system signals ***must*** be unambiguous, with a clear indication of the cause for the alarm or alert.

4.2.4 Accuracy.
Alarm and alert signals should convey information as to the level of danger and indicate the degree of malfunction or emergency.

4.2.5 Recognizability.
Alarms and alerts ***must*** be immediately recognizable as such under all operating conditions, including normal, emergency, and degraded modes. Such signals are recognized as auditory icons or "earcons".

4.2.6 Layout.
In the case of multiple simultaneous conditions, alarms and alerts ***must*** be grouped and prioritized within their group by their urgency, with alarms presented first followed by alerts.

4.2.7 Resistance to transient and random actuation.
Alarm and/or alert signals ***must*** not be actuated by transient or random sensor signals, such as with the use of appropriate averaging or filtering techniques.

4.2.8 Color.
Color ***must*** be used as a coding method in electronic displays.

4.2.9 Color Chromaticity.
For electronic color displays, chromaticity ***must*** be in accordance with the system specification and ***must*** ensure discernment of the alert message.

4.2.10 Visibility.
At any location, the alarm and alert signals ***must*** be testable and have a luminance and contrast that is fully readable.

4.2.11 Glare resistance.
Visual alarm and alert signals ***must*** be presented and located to minimize glare.

4.2.12 Reflection resistance.
Visual alarm and alert signals ***must*** be presented and located in such manner that reflections caused by the ambient light are minimized.

4.2.13 Visual interference backup.
Auditory alarm and alert backup ***must*** be provided in any area where the ambient illumination might interfere with the user's detection of the onset of the visual indication.

4.2.14 Fault indication compatibility.
When a parameter value represents a fault in some modes and not in others, it ***must*** only be alarmed in the appropriate modes.

4.2.15 Alarms settings access and transparency.
When alarm signals are based on user-defined logic, the system ***must*** allow the users to access current settings that are specified in terms of the dimensions (variables) covered and values (categories) established as alarms.

4.2.16 Alert settings access and transparency.
When alert signals are based on user-defined logic, the system ***must*** allow the users to access current settings that are specified in terms of the dimensions (variables) covered and values (categories) established alerts.

4.2.17 Explanatory auditory signal backup.
All nonverbal audio signals ***must*** be accompanied by a visual signal that defines the condition.

4.2.18 Supplementary visual displays.
When used in conjunction with a visual display, an audio signal ***must*** be supplementary or supportive, directing the user's attention to the appropriate visual display.

4.2.19 Help access.
When necessary, users ***must*** be able to request help and related information for the operation and processing of alarms, alerts, messages, and signals.

4.3 Implementation.

4.3.1 Organization by priority.
Alarms and alerts ***must*** be automatically organized and presented to the users in prioritized form, with the most significant alarms receiving the highest priority. This prioritization can be based on the immediacy of a required action.

4.3.2 Operational significance override.
The presentation of alarms and alerts with higher operational significance should automatically override the presentation of alarms and alerts with lower operational significance.

4.3.3 Presentation by priority (for simultaneous incidents).
When two or more incidents or malfunctions appear to occur simultaneously, the higher priority signal ***must*** be presented first. After presentation of the highest priority signal, remaining signals ***must*** be presented in descending order of priority.

4.3.4 Priority level limit.
The number of priority levels for alarm signals should be limited to four.

4.3.5 Distinctiveness and consistency.
Alarm and alert signals and messages ***must*** be distinctive and consistent for each class of event.

4.3.6 Understandability.
Presented alarm and alert information ***must*** be simple enough that users can easily evaluate the meaning and validity of the resulting signals and messages.

4.3.7 Separation of system status indication.
System status indicators should be presented in a separate grouping from the alarm and alert indicators.

4.3.8 Urgency filtering.
Alarms and alerts that have no current operational significance should be filtered.

4.3.9 Suppression of lesser alarms and alerts.
When a single alarm or alert event invariably leads to subsequent alarm or alert events, the primary event should be shown with the subsequent events suppressed, as long as it does not interfere with the user's tasks.

4.3.10 Suppressed event access.
When an event is suppressed, such as when its presentation may be postponed or filtered due to a flurry of higher priority activity, users ***must*** be able to access the information that is not presented.

4.3.11 Ease of access for suppressed events.
The method for accessing information on suppressed events should be procedurally simple.

4.3.12 Setpoint limits.
The setpoints for initiating alarm and alert signals ***must*** be set such that they:
a. Do not occur so frequently as to be considered a nuisance, and

b. Provide personnel adequate time to monitor and take appropriate action in a timely manner; before the situation escalates beyond the capability of the user to correct the problem.

4.4 Reliability.

4.4.1 Design for reliability.

The alarm and alert system ***must*** be designed so that no single point of failure within a system will result in the loss of a critical alarm or alert.

4.4.2 Component failures.

4.4.2.1 System failure.

In the event of a complete system failure, the system ***must*** integrate messages and report the system failure rather than the failure of components.

4.4.2.2 System or equipment failure.

The system devices and circuits ***must*** be designed to preclude alarm or alert signal failure in the event of system or equipment failure.

4.4.2.3 Display backup.

Where alarms and alerts are presented on an electronic display or similar unit as the primary display, users should be able to access the alarms and alerts from more than one display.

4.4.2.4 Flasher failure.

In the event of a flasher failure, the onset of an alarm or alert ***must*** cause the light to illuminate and burn steadily, rather than not illuminate.

4.4.3 Circuit checkout.

All system devices and circuits ***must*** be equipped with test devices or other means of testing the operation of the alarm and alert system to include the visual and auditory signals.

4.4.4 Input validation.

Alarm and alert system inputs (such as sensors) should be validated to ensure that spurious alarms or alerts are not presented to the user.

4.4.5 Noise filtering.

Alarm and alert systems ***must*** have the capability to filter out noise signals that can trigger alarms in error.

4.4.6 Loss of redundancy.
When part of a redundant system, unit of equipment, module, or component becomes inoperable, an alarm or alert signaling the loss of redundancy ***must*** be provided to the user immediately.

4.5 False and nuisance alarms and alerts.

4.5.1 False alarm and false alert rates.
False alarm and alert rates should be less than 2 percent (A false alarm rate of less than 2 percent means that in any given time period, the ratio of false alarms to actual alarms never exceeds 2 percent).

4.5.2 Nuisance alarms and alerts dependency.
The determination of alarm and alert setpoints ***must*** consider the trade-off between the timely alerting of an operator to an out-of-tolerance condition and the creation of nuisance alarms or alerts, but not at the expense of setting setpoints that do not allow sufficient advance warning to safely respond.

4.6 Maintainability.

4.6.1 Minimal interference.
The alarm and alert system ***must*** be designed so that maintenance activities can be performed with minimal interference with ongoing activities of the specialists / operators.

4.6.2 Out-of-service systems.
Taking a system or subsystem out of service to address an alarm or alert condition ***must*** require disabling the associated visual and audio signals.

4.6.3 Out-of-service indications.
Cues for prompt recognition of an out-of-service alarm or alert ***must*** be designed into the system.

4.6.4 Distinctive coding for illumination to support maintenance.
If an alarm or alert indicator must be illuminated for an extended period because of maintenance activities, it ***must*** be distinctively coded for positive recognition during this period.

4.6.5 Maintenance aids.
Aids should be provided, as needed, to assist personnel in performing alarm and alert system maintenance.

4.7 Recordkeeping.

4.7.1 Non-volatile record of alarm and alert history.

A capability ***must*** be provided to have all alarm and alert messages recorded in non-volatile memory or permanent storage media.

4.7.2 Alarm and alert record reset.

The stored history of alarms and alerts ***must*** be capable of being cleared by maintenance personnel when the existing record is no longer required.

4.8 Documentation.

4.8.1 Documentation support.

The alarm and alert system ***must*** be properly documented, with clear roles and responsibilities for maintaining and improving the system established using a defensible task analysis.

4.8.2 Access control process.

There ***must*** be a process established for handling access control and documentation of changes (properly documented and traceable) made to the alarm and alert system.

5 Detailed Requirements

5.1. Audio Presentation

5.1.1 Audio signal attributes.

5.1.1.1 Use.

Audio signals should be provided (as necessary) to warn personnel of impending danger, to alert a user to an out-of-tolerance change in system or equipment status, to alert the user to the existence of a new alarm or alert, to remind a user of critical actions that must be taken, or any other condition of which the user must be made immediately aware.

5.1.1.2 Purpose.

Auditory signals should be used only when such signals contribute to understanding of and appropriate responses to the operational and task environment. An audio signal should be provided when any of the following conditions apply:

a. The information to be processed is short, simple, transitory, and requires an immediate or time-based response.

b. The use of a visual display might be inappropriate because of overburdening of the visual modality, ambient light variability or limitation, user mobility, degradation of vision by vibration, other environmental considerations, or anticipated user inattention.

c. The criticality of a response to a visual signal makes supplementary or redundant alerting desirable.

d. It is desirable to warn, alert, or cue the user for subsequent or additional responses.

e. Practice has created an expectation for an audio signal.

f. Voice communication is necessary or desirable.

5.1.1.3 Environment compatibility.

The intensity, duration, and source location of audio alarms and signals ***must*** be compatible with the acoustical environment of the intended receiver.

5.1.1.4 Detectability.
Each audible alarm and alert signal ***must*** be detectable in all locations where personnel may be positioned when their response to the condition is required.

5.1.1.5 Appropriateness.
When an audio signal is used, the particular type of signal (tone, complex sound, or speech) should be appropriate for the intended use.

5.1.1.5.1 Alarm signal profile – active channel pattern.
The alarm signal should be a complex tone that sounds four times in relatively rapid succession followed by approximately 4 seconds of silence; and repeats until acknowledged.

5.1.1.5.2 Alarm signal profile – backup channel pattern.
The alarm signal for a backup (non-active channel) should be a double-beep complex tone that sounds three times in relatively rapid succession followed by approximately 4 seconds of silence; and repeats until acknowledged.

5.1.1.5.3 Alarm signal profile - testing or training channel pattern.
The alarm signal for use during testing and/or training should be a "sonar ping" complex tone that sounds three times in relatively rapid succession followed by approximately 4 seconds of silence; and repeats until acknowledged.

5.1.1.5.4 Alert signal profile – active channel pattern.
The alert signal should be a complex tone that sounds once followed by approximately 3 seconds of silence; and repeats until acknowledged. This provision also applies to the primary (active) channel of a system that has a primary and backup (non-active) channel.

5.1.1.5.5 Alert signal profile – backup channel pattern.
The alert signal should be a double-beep complex tone that sounds once followed by approximately 3 seconds of silence; and repeats until acknowledged.

5.1.1.5.6 Alert signal profile – testing or training channel pattern.
The alert signal for use during testing and/or training should be a "sonar ping" complex tone that sounds once followed by approximately 3 seconds of silence; and repeats until acknowledged.

5.1.1.6 Operational usability.
Auditory signals ***must*** be tested and evaluated for usability, operational suitability, and user acceptance using representative users in as near to a realistic operational environment as possible before the signals are incorporated into a system.

5.1.1.7 Setpoint flexibility.

When appropriate to the task, a system or application ***must*** allow a user to set the parameter or condition that results in a software-generated alarm, alert, or status message that is consistent with the need.

5.1.1.8 Setpoint limits.

User setting of parameters ***must*** not be allowed when the settings by one user might affect the reception of alarms and alerts by another user; when the settings might affect the safety of personnel, systems, and equipment; or when the alarm and alert parameters are determined by functional, procedural, or legal requirements.

5.1.1.9 Effectiveness.

Signals should facilitate appropriate responses and not startle the user in a manner that hinders response, or in any way interferes with other functions by diverting attention away from other critical signals.

5.1.1.10 Auditory feedback.

Where auditory feedback is useful, such as to confirm actuation of a response, the most common auditory feedback, the system beep, should be used with other forms of notification such as flashing or message dialogs.

5.1.2 Audio signal characterization

5.1.2.1 Number of signals.

5.1.2.1.1 Limits on number of signals for absolute identification.

When absolute identification is required, the number of signals to be identified should not exceed four.

5.1.2.1.2 Limits on number of signals for relative identification.

For relative identification, the number of signals to be identified should not exceed 12.

5.1.2.1.3 Single audio signal exception.

A single audio signal should be used in conjunction with multiple visual displays only if immediate identification of the appropriate visual display is not critical to the safety of personnel or system performance.

5.1.2.2 Signal attributes.

5.1.2.2.1 Discernibility.
Auditory signals that require different user responses ***must*** be easily distinguishable from one another.

5.1.2.2.2 Differentiability (alarm versus alert).
Audible signals to denote an alarm condition ***must*** be noticeably different from audible signals identifying an alert condition.

5.1.2.2.3 Differentiation from routine signals.
Audio alarms and alerts intended to attract the user's attention to a malfunction or failure ***must*** be different from routine signals such as bells, buzzers, random noises generated by air conditioning and other equipment, and normal operation noises.

5.1.2.2.4 Distinctiveness.
When several different audio signals will be used to alert a user to different conditions, the signals ***must*** be distinctive in intensity, pitch, or use of beats and harmonics.

5.1.2.2.5 Operational suitability.
Auditory signals ***must*** not be used if they resemble sounds that can occur in the actual operational setting, such as sounds that are similar to navigational signals or radio transmissions, or hisses or humming sounds similar to electrical interference.

5.1.2.2.6 Compatibility.
Audio alarm and alert signals ***must*** not interfere with any other critical functions or signals, mask other critical audio signals, or conflict with other auditory signals.

5.1.2.3 Signal meaning.

5.1.2.3.1 Meaning consistency.
The meaning of audio alarm and alert signals selected for a particular function in a system ***must*** be consistent with signal meanings already established for that function.

5.1.2.3.2 Compatibility with ambient environment.
Established signals should be used provided they are compatible with the acoustic environment and voice communication systems.

5.1.2.3.3 Signal predictability.
Established signals ***must*** not be used to convey new meanings.

5.1.2.4 Profile construction guidance.

5.1.2.4.1 Intermittence.
Auditory signals should be intermittent rather than continuous.

5.1.2.4.2 Signal composition complexity.
Auditory signals should be constructed from complex sounds, for example, timbres rather than from pure tones.

5.1.2.4.3 Alarm (Warning) signal content.
Audio alarm signals should consist of two elements, an attention-getting signal and an identifying or action signal.

5.1.2.4.4 Modulation guidance.
Modulated alarm and alert signals should provide either beeping sounds (from 1 to 8 beeps per second) or warbling sounds (that rise and fall in pitch from 1-3 Hz).

5.1.2.4.5 Critical situation attention getting.
When reaction time is critical and a two-element signal is used, an attention-getting signal of 0.5 seconds duration ***must*** be provided followed by an identifying or action signal, with all essential information being transmitted in the first 2 seconds of the identifying or action signal.

5.1.2.4.6 Minimum information content for single-element signals.
Information in a single-element audio signal ***must*** be transmitted in the first 0.5 seconds.

5.1.2.4.7 Minimum Duration.
Audio alarm and alert signal duration ***must*** be at least 0.5 seconds and may continue until the appropriate response is made.

5.1.2.4.8 Signal termination.
Completion of a corrective action by the user or by other means ***must*** automatically terminate the signal.

5.1.2.5 Frequency discernability.

5.1.2.5.1 Frequency audibility.
The frequency range of an alarm or alert signal ***must*** be between 200 and 5,000 Hz, preferably between 500 and 3,000 Hz.

5.1.2.5.2 Cluttered environment audibility.
When the signal must be heard around obstacles or through partitions, the frequency ***must*** be below 500 Hz.

5.1.2.5.3 Discriminability.
The selected frequency band ***must*** differ sufficiently from the most intense background frequencies to enable discrimination.

5.1.2.5.4 Spurious signals.
The frequency of an alarm or alert tone ***must*** be different from that of the electric power employed in the system to preclude the possibility that a minor equipment failure might generate a spurious signal.

5.1.2.5.5 Directional discernibility & localization.
Mid-frequencies (1,500-3,000 Hz) should not be used for auditory alarms and alerts that require localization.

5.1.2.6 Signal Intensity (loudness).

5.1.2.6.1 Frequency audibility.
An alarm or alert signal ***must*** provide an audio level (at least one octave band between 200 and 5,000 Hz) so that the sound pressure level (SPL) of the signal is at least 10 dB(A) above the ambient noise level, or 20 dB(A) above the amplitude of the masked threshold (or at such a level that assures personnel are adequately alerted to the danger or status) when measured within a foot (1 foot) of the responder's ear or at more than 2 feet from the signal.

5.1.2.6.2 Environmental compatibility.
The intensity, duration, and source location of an auditory signal should be compatible with the acoustic environment of the intended receiver as well as with the requirements of other personnel within acoustic range of the signal.

5.1.2.6.3 Signal-to-noise thresholds and limits.
Auditory signals ***must*** exceed the prevailing ambient noise level by at least 10 dB(A), without exceeding 115 dB(A) for emergency signals or 90 dB(A) for other signals.

5.1.2.6.4 Maximum intensity limits.

The intensity of evacuation and emergency signals ***must*** not exceed 115 dB(A). The intensity of other signals ***must*** not exceed 90 dB(A).

5.1.2.6.5 Clothing and equipment compatibility.

When the audio signals must be heard and understood through equipment or garments (e.g., parka hoods and hearing protective devices covering the ears of a listener), audio signals ***must*** be loud enough to compensate for the attenuation characteristics of the garments, without exceeding 115 dB(A) for emergency signals and 90 dB(A) for other signals.

5.1.2.6.6 Volume control capabilities.

The user, the sensing mechanism, or both ***must*** control the volume (loudness) of an audio signal depending on the operational situation and the safety of personnel.

5.1.2.6.7 Volume control restrictions.

Volume control movement ***must*** be restricted to prevent reducing the volume to an inaudible level or increasing it to an unacceptably high level.

5.1.2.6.8 Intensity coding restriction.

Auditory signals should not be coded by intensity.

5.1.3 Audio signal acknowledgement.

5.1.3.1 Acknowledgement and termination capabilities.

A system or application ***must*** provide users with a means of acknowledging alarms and alerts as well as a means of turning off alarm and alert signals once they have been acknowledged or the condition generating the signal has been corrected.

5.1.3.2 Special acknowledgment capability.

When a user must acknowledge a special or critical alarm or alert in a unique way (e.g., with a special combination of key strokes), this special acknowledgment ***must*** not inhibit or slow the response to the condition initiating the alarm or alert.

5.1.3.3 Reset capability.

A system or application ***must*** provide users with a simple means for turning off non-critical auditory alarms or alerts without erasing any displayed message that accompanies the auditory signal.

5.1.3.4 Procedural efficiency.
Procedures for acknowledgment and termination of alarms and alerts ***must*** not hamper the speed and accuracy of operator reaction to the alerting situation.

5.1.3.5 Procedural consistency.
A simple, consistent means of acknowledging auditory signals ***must*** be provided.

5.1.3.6 Loss of redundancy awareness.
Users ***must*** be able to acknowledge an alarm signaling the loss of redundancy, with the lack of available redundancy continuously displayed, until the redundant system, equipment, module, or component becomes operable again.

5.1.3.7 Automatic reset.
An automatic reset function for audio signals ***must*** be provided, whether the signals are designed to terminate automatically, manually, or both. The automatic reset function ***must*** recycle the signal system such that the system can sound again if the condition reappears.

5.1.3.8 Volume control banding.
Volume controls should be banded to mode switches to provide maximum output during operational phases in which intense noise can occur and to provide reduced volume at other times.

5.1.3.9 Volume control banding restriction.
Volume control banding ***must*** not be done if there is a possibility that intense noise could occur in an emergency situation during a phase in which the volume would be decreased below an audible level.

5.1.4 Headset Presentation.

5.1.4.1 Automatic headset presentation.
When a person wears earphones that cover both ears during normal equipment operation, the audio signal ***must*** be directed to the headset as well as to the work area.

5.1.4.2 Usage exceptions.
Binaural headsets should not be used in any operational environment with ambient noise below 85 dB(A) if the environment contains sounds that provide useful information but that information cannot be directed to the person's headset.

5.1.4.3 Signal separation.
When feasible, an alarm or alert signal delivered to a headset that might mask another essential audio signal should be delivered to one ear and the other signal to the other ear.

5.1.4.4 Dichotic presentation.
When earphones will be worn in an operational environment, a dichotic presentation should be used whenever feasible, with the signal alternating from one ear to the other by means of a dual-channel headset.

5.1.5 Voice (verbal) alarm and alert signals.

5.1.5.1 Use.
Caution should be applied when deciding on the use of verbal alarm and alert signals. Voice signals should be used for the following:

a. To supplement visual displays when communication flexibility is necessary.

b. When coded signal meanings are numerous or may be forgotten.

c. For presentation of complex directions or instructions.

d. When ambient noise may mask simple tonal signals.

e. In conjunction with tonal signals.

f. For presentation of continuous information when the rate of change is low.

5.1.5.2 Speech limitation.
Speech ***must*** not be used as the sole means of providing alarm and alert information. Speech should only be used to augment alarm and alert information provided in other modalities.

5.1.5.3 Voice standardization.
Voice signals ***must*** consist of a brief, standardized speech signal (e.g., a verbal message) to identify the specific condition and suggest an appropriate action.

5.1.5.4 Non-vocal precursor.
Voice signals should be preceded by an initial non-speech alerting signal to attract the user's attention, particularly if verbal messages are used for other types of information as well as alarms or alerts.

5.1.5.5 Acknowledgement response.
The system should require that users acknowledge spoken alarm or alert signals.

5.1.5.6 Intensity. (Message Volume)

5.1.5.6.1 Intensity thresholds and limits.
Verbal signals for critical functions ***must*** be at least 20 dB above the speech interference level at the operating position of the intended receiver but ***must*** not exceed 90 dB(A).

5.1.5.6.2 Signal-to-noise thresholds.
Speech intensity should be appropriate to the expected ambient noise environment, with a signal to noise ratio of at least 5:1, but without exceeding the "Intensity Thresholds and Limits" of 5.1.5.6.1.

5.1.5.6.3 Speech intensity limits.
When a signal must be relatively intense because of high ambient noise, peak clipping may be used to protect the listener against auditory overload, if used without adverse impact to information content.

5.1.5.7 Message presentation and content.

5.1.5.7.1 Word selection.
The words used in verbal signals ***must*** be intelligible, concise, and appropriate to the task and the information presented. Words ***must*** be selected based on intelligibility, descriptiveness, and conciseness, in that order.

5.1.5.7.2 Phrasing preferences.
To the extent possible, words that rhyme with other words or that sound similar in other ways should be avoided if these other words might be used in the same context and, therefore, possibly be confused with the original words.

5.1.5.7.3 Phrasing preferences restrictions.
When implementing phrasing preferences to avoid confusion in interpretation, the impacts of the differences in how hearing impaired persons hear should be considered.

5.1.5.7.4 Formal message preference.
Formal or correct words should be used; slang, jargon, and colloquial words should be avoided.

5.1.5.7.5 Alphabetic information presentation.
Alphabetic information should be presented using a phonetic alphabet that uses words like Alpha, Bravo, and Charlie rather than the letters A, B, and C.

5.1.5.7.6 Message commencement.
The signal, when activated, ***must*** always start at the beginning of the message.

5.1.5.7.7 Standard dialect delivery.
Spoken messages should sound like an average talker from the user country without a regional dialect. Voice signals should be presented in a formal, impersonal manner.

5.1.5.7.8 Distinctive voices.
When different categories of voice signals are used, a different, distinctive voice should be used for each category of data.

5.1.5.7.9 Essential content.
Spoken messages should be brief, informative, and to the point.

5.1.5.7.10 Message structure.
The structure for verbal alarms and alerts ***must*** be

a. general heading such as the system or service involved;

b. specific subsystem or location; and

c. nature of emergency.

5.1.5.7.11 Voice attributes.
The voice used in recording verbal signals ***must*** be distinctive, mature, without dialect, and presented in a formal, impersonal manner.

5.1.5.7.12 Repetition pattern for critical signals.
Critical alarm and alert signals ***must*** be repeated with not more than a 3-second pause between messages until the condition is corrected or overridden by the user.

5.2 Visual Presentation

5.2.1 Display Requirements.

5.2.1.1 Displays.

5.2.1.1.1 Readability.
Display luminance and contrast ***must*** be such that alarm and alert messages are easily readable from the design eye position in any operational ambient lighting condition.

5.2.1.1.2 Discrimination.
Luminance and contrast of color displays ***must*** ensure the discrimination of the alarm and alert message from the background.

5.2.1.1.3 Contrast detection.
There ***must*** be sufficient contrast between flashing and fully illuminated alarms and alerts, and between illuminated and non-illuminated alarms and alerts, so personnel can reliably discriminate each state.

5.2.1.1.4 Luminance for electronic display presentation.
For electronic display presentations, either the symbol or its background, whichever luminance is higher, should be 35 cd/m^2 or more.

5.2.1.1.5 Contrast Ratio. .
The contrast ratio between the symbol and the surrounding background should be at least 3:1, with 7:1 preferred.

5.2.1.1.6 Dimming limits.
The display ***must*** be prevented from being dimmed to such a level that would make the alarm or alert message unreadable.

5.2.1.2 Controls.
The requirements for control and display integration ***must*** be as specified in the FAA HF-STD-001 section appropriate to the control-display technology being used.

5.2.1.2.1 Control and display integration.
The requirements for control and display integration ***must*** be as specified in the FAA HF-STD-001 section appropriate to the control-display technology being used.

5.2.1.2.2 Core command consistency.
Core commands, if used, ***must*** use consistent terminology across systems so that different commands are not used to accomplish the same functions, or the same or similar commands are not used to accomplish different functions.

5.2.1.3 Characters and shapes.

5.2.1.3.1 Legibility.
Specific display design characteristics ***must*** determine the minimum number of message lines to be displayed, allowing for the need to have characters large enough to be legible to users in their normal working positions.

5.2.1.3.2 Legend Layout.
Legends, including abbreviations, should be constructed so that any legend will fit on one line.

5.2.1.3.3 Legends and Abbreviations.
Legends and abbreviations ***must*** be in accordance with text coding requirements of FAA HF-STD-001.

5.2.1.3.4 Letters and Numbers.
Letters and numbers on electronic displays should be in conformance with the appropriate requirements of the FAA HF-STD-001 section related to the control-display technology being used.

5.2.1.3.5 Dimensions and spacing.
Character dimensions and spacing ***must*** be selected for speed and accuracy of interpretation and ***must*** be in accordance with FAA HF-STD-001.

5.2.1.3.6 Character and symbol heights.
The height of symbols and characters ***must*** subtend a viewing angle of no less than 20 minutes of arc when measured from the design eye position.

5.2.1.3.7 Character and font approval.
Character dimensions and fonts ***must*** be evaluated and approved by the acquiring activity before implementation.

5.2.2 Visual Presentation Details.

5.2.2.1 Presentation Layout.

5.2.2.1.1 Location preference (within operator's cone of vision).
Unless otherwise specified, all alarm and alert messages should be presented within the operator’s 30 degree (total included angle) forward cone of vision, on a single display surface.

5.2.2.1.2 Left preference for alerts for multiple displays.
If more than one display is present, the display monitor or panel farthest to the left should present the alarm and alert messages.

5.2.2.1.3 Anthropometric preference.
If interactive control functions are included with the display, they ***must*** be within the anthropometric reach of the operator using them.

5.2.2.1.4 Consistency of arrangement and relative location.
Repetitively appearing groups of alarms and alerts ***must*** have the same arrangement and relative location on different panels and consoles. All alarm and alert controls that appear in more than one location ***must*** be consistently placed on panels and consoles.

5.2.2.2 Message presentation.

5.2.2.2.1 Alarm message precedence.
The presentation of alarm messages ***must*** have precedence over alert messages and routine display information.

5.2.2.2.2 Alert message precedence.
The presentation of alert messages ***must*** have precedence over routine display information.

5.2.2.2.3 Dedicated location.
Whenever one or more alarm or alert conditions are present, the message(s) ***must*** appear in a location dedicated for the presentation of alarm and alert messages.

5.2.2.2.4 Overwrite priority.
The alarm or alert message location may blank out any display symbology or video when presenting a message, as long as the action does not hinder the operator's ability to deal with the problem.

5.2.2.2.5 Required message area.
Only the appropriate active alarm or alert message(s) ***must*** appear; however, the location for presenting the alarm and alert messages ***must*** be large enough to present at least as many messages as there are alarms within the system.

5.2.2.2.6 Message acknowledgement.
After the operator has acknowledged an alarm or alert, the system should change to a visually distinct acknowledged state.

5.2.2.2.7 Essential content.
Alarm and alert messages ***must*** concisely convey the nature of the problem and the specific subsystem or location.

5.2.2.2.8 Standard syntax preference.
A standard syntax ***must*** be subordinate to a clear statement of the problem.

5.2.2.2.9 Urgency ordering.
Messages should be grouped by urgency level, with the highest priority messages listed first.

5.2.2.2.10 Grouping capabilities.
In addition to priority grouping, users should have the capability to group messages according to operationally relevant categories such as function, chronological order, and status.

5.2.2.2.11 Setpoint limit setting.
If an alarm or alert condition requires verification before action is taken, the relevant setpoint limits should be included in the alarm or alert message when the information on an electronic display or similar display.

5.2.2.2.12 Out-of-tolerance parameter highlighting.
Out-of-tolerance parameter values should be highlighted in the alarm or alert message when the alarm or alert information is presented on an electronic display or similar display.

5.2.2.2.13 Minimum message duration.
In order to ensure that an operator has adequate opportunity to identify the alarm or alert condition, a minimum message display time of 3 seconds is suggested for all alarm and alert messages.

5.2.2.2.14
Every presented alarm and alert ***must*** be recorded with qualifying context information for later retrieval.

5.2.2.3 Message tracking.

5.2.2.3.1 Display overflow recall.
A system to retrieve and display messages stored in overflow memory ***must*** be used when the number of active messages exceeds the capacity of the display.

5.2.2.3.2 Operator action pending indicator.
Alarm and alert messages ***must*** remain presented until either the causative condition has been corrected or the operator takes an action to store the message in overflow memory for later recall.

5.2.2.3.3 Display overflow limit indicator.
If there are more messages than there is space to display them all, an indication ***must*** be provided to the operator that additional alerts exist.

5.2.2.3.4 Storage and recall capability.
Overflow messages ***must*** be stored, and a capability ***must*** be provided to recall/scroll through stored alarms and alerts.

5.2.2.3.5 New messages.
In the event a new alarm or alert condition arises:

a. The new message ***must*** be placed with messages of equal criticality.

b. If space is limited on the display, a message of lower criticality ***must*** be replaced, but retained in memory.

c. The replaced message ***must*** be moved into overflow.

d. If no lower criticality message exists, a message of equal criticality ***must*** be moved into overflow.

e. Messages placed in overflow ***must*** be grouped with messages of equal criticality.

5.2.2.4 Message Coding.

5.2.2.4.1 General.

5.2.2.4.1.1 Coding effectiveness.
The coding scheme(s) used in the alarm and alert system ***must*** ensure rapid detection and interpretation by users under all expected operating conditions.

5.2.2.4.1.2 Coding complexity.
The number of different coding techniques ***must*** be kept to a minimum, so that the coding system does not become too difficult to use or understand.

5.2.2.4.1.3 Color coding as primary coding mechanism.
Based on its strong attention getting qualities, color ***must*** be used as a primary coding mechanism to convey visual alarm and alert status.

5.2.2.4.1.4 Judicious use.
Coding techniques that have strong attention-getting qualities (for example, color and flashing) should be used judiciously.

5.2.2.4.1.5 Consistency.
The coding conventions that are used should be applied consistently within a system and across related systems.

5.2.2.4.1.6 Special coding exceptions.
Although special coding should be avoided where possible, it may be the case that the user's needs that relate to a system require a special coding. If a coding value is assigned a special meaning in a display, the meaning should be defined at the bottom of the display.

5.2.2.4.1.7 Code mapping restrictions.
Individual users should not be able to change the status codes that are mapped to different system states and conditions.

5.2.2.4.1.8 Functional coding.
When coding is used, it ***must*** be functional and meaningful (rather than decorative and arbitrary).

5.2.2.4.1.9 Coding redundancy.
Redundant coding ***must*** be used for alarms and alerts that require rapid action.

5.2.2.4.2 Color coding.

5.2.2.4.2.1 Emphasis/ meaning enhancement.
In general, color should be used to reinforce or augment a user's understanding of the information being presented, such as: to attach specific meaning to a portion of text or a symbol, to direct a user's attention to something (highlighting critical elements), to reduce clutter, to identify and classify information, to indicate changes in status (as a formatting aid), and to enhance legibility.

5.2.2.4.2.2 Consistency.
Colors ***must*** be used consistently within a screen, within a system, and across related systems.

5.2.2.4.2.3 Conservative use.
Color should be used conservatively. Color should be used only if it facilitates user performance or understanding; and the total number of colors used for coding should not exceed four for a single alphanumeric screen and seven for a set of related screens.

5.2.2.4.2.4 Predictable meaning.
Well-established meanings should be retained, limiting one meaning per color.

5.2.2.4.2.5 Color meaning.

a. Red. Red ***must*** be used to indicate conditions such as no-go, error, failure, alarm, or malfunction.

b. Flashing red. Flashing red ***must*** only be used to indicate an emergency condition requiring immediate action and ***must*** continue until the emergency condition has been acknowledged.

c. Yellow. Yellow or amber ***must*** be used to indicate marginal conditions, caution, or alert.

d. Green. Green should be used to indicate that it is OK to proceed, normal, satisfactory, or within tolerance status.

e. White. White ***must*** indicate alternative functions or system conditions that do not have operability or safety implications.

f. Blue. Blue should be used only for advisory or informational items.

g. Gray. Items that are unmonitored, unmanaged, inactive, out of service for a long term, or intentionally taken off-line, should be coded as Aviation Gray at the topmost level to indicate that the user can ignore these items.

h. Color key. If the use of color does not follow well-established meanings, or if a color is used for which there is no conventional association, a color key ***must*** be readily accessible for the user.

5.2.2.4.2.6 Color-coded symbol size.
A symbol that is color-coded ***must*** subtend a visual angle of at least 20 minutes.

5.2.2.4.2.7 Color-coded symbol luminance.
Color-coded symbols ***must*** have a minimum luminance of 3.5 cd/m^2.

5.2.2.4.2.8 Color-coded symbol refresh.
Color-coded symbols ***must*** have a refresh rate that provides no perceptible flicker.

5.2.2.4.3 Flash (blinking) coding.

5.2.2.4.3.1 Urgency indication.
Flash coding should only be used to indicate a situation with an urgent need for user attention.

5.2.2.4.3.2 Flash rate parameters.
Where one flash rate is used, the rate ***must*** be between 3 and 5 Hz with an on/off cycle of approximately 50 percent.

5.2.2.4.3.3 Flash rate constraints.
No more than two flash rates ***must*** be used.

5.2.2.4.3.4 Flash rates and urgency emphasis.
If multiple flash rates are used to indicate alarms and alerts, a faster flash rate should indicate greater urgency than a slower flash rate.

5.2.2.4.3.5 Second flash rate.
Where two flash rates are used, the second rate ***must*** be 1-2 Hz.

5.2.2.4.3.6 Synchronization of simultaneous flashes.
Where two flash rates are used, flashing presentations that could be simultaneously active should have synchronized flashes.

5.2.2.4.3.7 Flash rate restrictions.
Flashing ***must*** never exhibit rates of 10 to 25 Hz to minimize the risk of seizures for those with photosensitive epilepsy.

5.2.2.4.4 Alphanumeric coding.

5.2.2.4.4.1 Meaningful coding.
Alphanumeric codes should be meaningful rather than arbitrary.

5.2.2.4.4.2 Redundant coding.
Alphanumeric coding should not be the sole means of drawing attention to an alarm or alert.

5.2.2.4.4.3 Consistency.
Alphanumeric codes should use either uppercase or lowercase letters; and be used consistently.

5.2.2.4.4.4 Lowercase letter sizing.
If lowercase letters are used, the character height of text, depending on viewing distance, should be between 20 and 22 minutes of arc, with a minimum of 16 minutes of arc.

5.2.2.4.4.5 Letter and number use.
If the coding includes letters and numbers, the letters should be grouped together and the numbers should be grouped together rather than interspersing letters and numbers.

5.2.2.4.4.6 Label clarity.
If letters and numbers are used in a label, the letters and numbers ***must*** be easily distinguishable; that is, avoid easily confusable letters and numbers such as "Z" and "2" or "O" and "0".

5.2.2.4.4.7 Punctuation limits.
Punctuation should be avoided in alphanumeric codes.

5.2.2.4.4.8 Explicitly defined coding.
Arbitrary codes or codes that are to be recalled by the users ***must*** be avoided.

5.2.2.4.4.9 Numeric codes.
Purely numeric codes should be avoided.

5.2.2.4.5 Brightness coding.
Brightness coding should only be used as a redundant coding.

5.2.2.4.5.1 Brightness coding limits.
When brightness coding is used, the number of brightness levels should not exceed three, with two levels as optimal.

5.2.2.4.5.2 Criticality and brightness.
The brighter of the two levels should be used to code the more critical item, with the luminance levels differing by a ratio of 2:1.

5.2.2.4.5.3 Consistency.
Brightness coding should have a consistent meaning within a system and across related systems.

5.2.2.4.6 Highlighting.

5.2.2.4.6.1 Dark background highlighting preference.
When highlighting is used on dark backgrounds, the highlighting should be white with dark text.

5.2.2.4.6.2 Light background highlighting preference.
When highlighting is used on light backgrounds, the highlighting should be dark with white text.

5.2.2.4.6.3 Reverse video use.
If reverse video (brightness inversion) is used to draw the user's attention to an alarm or alert, displayed text should return to normal after the user has responded, or when the alarm or alert no longer exists.

5.2.2.4.7 Shape coding.

5.2.2.4.7.1 Shape discernibility.
Shapes used for alarms and alerts should be clearly discernable from one another, avoiding similar geometric forms.

5.2.2.4.7.2 Identifiability without reference.
Where geometric shape coding is used and each shape is required to be identified without reference to any other, the number of shapes in the entire set, including alarms and alerts, should not exceed five.

5.2.2.4.7.3 Screen resolution.
The screen resolution ***must*** be adequate to allow the user to readily differentiate shapes under operational conditions.

5.2.2.4.8 Size coding.

5.2.2.4.8.1 Presented in largest size.
When used, alarms and alerts ***must*** be presented in the largest size of those in use on the display.

5.2.2.4.8.2 Relationship to smaller size.
The largest size should be 1.5 times the height of the next smaller size.

5.2.2.4.9 Location (spatial) coding.

5.2.2.4.9.1 Location prominence.
Alarms and alerts ***must*** be assigned the most prominent position within a display; typically either the center of the screen or the top left.

5.2.2.4.9.2 Location consistency.
Alarms and alerts ***must*** occupy the same general location within a system and across related systems.

5.2.2.4.10 Symbol coding.
Symbol coding, though uncommon, may be used in alarm and alert status displays to indicate whether or not an item has been acknowledged.

5.2.2.5 Mechanical visual signals.

5.2.2.5.1 Use.
When mechanical visual signals are used, the signal ***must*** be in accordance with the FAA HF-STD-001 section appropriate to a given type of signal device.

5.2.2.5.2 Color.
Mechanical visual signals should have white markings on a black background or as specified by the acquiring activity.

5.2.2.5.3 Markings.
Mechanical visual signals ***must*** be marked with a legend or symbol that is descriptive of the information being given.

5.2.2.5.4 Luminance of flags.
The markings on flags ***must*** be as luminous as the markings on the indicator or display in which it is mounted.

5.2.2.5.5 Luminance of indicators.
Indicator luminance for lighted displays ***must*** be in accordance with FAA HF-STD-001.

5.3 Tactile Presentation

5.3.1 Use.
If tactile signals are used, they should be of such amplitude as to be detected by the part of the body being stimulated, and they should be delivered by an apparatus that will always be in contact with the body.

5.3.2 Coding.
Tactile signals ***must*** be coded so as not to be misconstrued as a normal vibration of the equipment or workstation.

5.3.3 Prior approval.
Any use of tactile signals should have prior approval by the acquiring organization.

6 Notes

6.1 Intended use

This standard is intended for use in acquisition to obtain unique tools and systems for FAA Air Traffic Control (ATC) Operations. Non-Government standards or commercial item descriptions should be used to describe the requirements for commercially available items.

6.2 Tailoring Guidance

To ensure proper application of this standard, invitation for bids, requests for proposals, and contractual statements of work should tailor the requirements in sections 4 and 5 of this standard to exclude any unnecessary requirements.

6.3 Preparing activity

This document was prepared by the FAA Human Factors Division (ANG-C1) in collaboration with the FAA Air Traffic Organization's Program Management Organization, Enterprise Services, Program Engineering Services Group, Specialty Engineering Team (AJM-352).

Federal Aviation Administration
Human Factors Division ANG-C1
800 Independence Ave SW
Washington, DC 20553

Appendix A. Acronyms

ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ASWG	Alert Standard Working Group
ATC	Air Traffic Control
ATO	Air Traffic Organization
CCB	Configuration Control Board
CM	Configuration Management
COTS	Commercial-Off-The-Shelf
DoD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
EPRI	Electric Power Research Institute
FAA	Federal Aviation Administration
FAMS	FAA Acquisition Management System
GPO	Government Printing Office
HDBK	Handbook
HF	Human Factors
Hz	Hertz
ICAO	International Civil Aviation Organization
IEC	International Electrotechnical Commission
ISO	International Standards Organization
LOS	Line-of-Sight
MIL	Military
NAS	National Airspace System
NDI	Non-developmental Item
NUREG	Nuclear Regulation
STD	Standard
TO	Tower Operations

Appendix B. References

This Appendix is not a mandatory part of the standard. The information contained herein is intended for guidance only.

Ahlstrom, V., & Longo, K. (2000). William J. Hughes Technical Center auditory alarm database [CD-ROM]. Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Ahlstrom, V., & Muldoon, R. (2002). A catalog of graphic symbols used at maintenance control centers: Toward a symbol standardization process (DOT/FAA/CT-TN02/12). Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Ahlstrom, V., & Muldoon, R. (2003). Core commands across Airway Facilities systems (DOT/FAA/CT-TN03/15). Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Ahlstrom, V., & Muldoon, R. (2004). Visual coding of status for Technical Operations systems (DOT/FAA/CT-TN04/20). Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Ahlstrom, V., & Panjwani, G. (2003). Auditory alarms in the Airways Facilities environment (DOT/FAA/CT-TN04/04). Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Allendoerfer, K., Friedman-Berg, F., & Pai, S. (2007). Human factors analysis of safety alerts in Air Traffic Control (DOT/FAA/TC-07/22). Atlantic City International Airport, NJ: Federal Aviation Administration William J. Hughes Technical Center.

Ameritech Services Incorporated. (1996). Ameritech graphical user interface standards and design guidelines. Chicago, IL: Robert M. Schumacher, Jr.

Avery, L.W., & Bowers, S.E. (Eds.) (1992). Department of Defense human-computer interface style guide Version 2.0 (DOE HFDG ATCCS V2.0 also known as DOD HCISG V2).

Billings, C. E. (1996). Human–centered aviation automation: Principles and guidelines. Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center.

Brewster, S. A., Wright, P. C., & Edwards, A. D. N. (1993). An evaluation of earcons for use in auditory human-computer interfaces. INTERCHI 1993 Conference Proceedings, 222-227.

Brown, W., O'Hara, J., & Higgins, J. (1999). Advanced alarm systems: Revision of guidance and its technical basis (NUREG/CR-6684). Washington, DC: U.S. Nuclear Regulatory Commission.

Chan, A. H. S., & Ng, A. W. Y. (2009). Perceptions of implied hazard for visual auditory alerting signals. Safety Science, 47, 346-352.

Chapanis, A. (1996). Human factors in systems engineering. New York: John Wiley & Sons.

CTA Incorporated. (1996). User-interface guidelines (DSTL-95-033). Greenbelt, MD: Goddard Space Flight Center (Code 520).

Deatherage, B. H. (1972). Auditory and other sensory forms of information processing. In H. P. Van Cott & R. G. Kincade (Eds.), Human Engineering Guide to Equipment Design. Washington DC: American Institutes for Research.

Department of Defense, Washington, DC: Defense Information Systems Agency.

Department of Defense. (1987). User/computer interface (MIL-STD-1801). Philadelphia, PA: Navy Publishing and Printing Office.

Department of Defense. (1989). Human engineering guidelines for management information systems (MIL-HDBK-761A). Philadelphia, PA: Navy Publishing and Printing Office.

Department of Defense. (1990). Human engineering performance requirements for systems (MIL-STD-1800A). Philadelphia, PA: Navy Publishing and Printing Office.

Department of Defense. (1995). Human engineering design guidelines (MIL-HDBK-759C).Washington, DC: U.S. Department of Defense.

Department of Defense. (1995). Human engineering design guidelines (MIL-HDBK-759C). Washington, DC: U.S. Department of Defense.

Department of Defense. (1997). Aircrew station alerting systems (MIL-STD-411F). Washington, DC: U.S. Department of Defense.

Department of Defense. (1999). Human engineering (MIL-STD-1472F). Washington, DC: U.S. Department of Defense.

Department of Energy. (1985). Human factors design guidelines for maintainability of Department of Energy Nuclear Facilities (UCRL-15673). Washington, DC: United States Department of Energy.

Department of Energy. (1992). Human factors engineering design criteria (DOE-HFAC1). Washington, DC: U.S. Department of Energy.

Department of Energy. (2001). Human factors/ergonomics handbook for the design for ease of maintenance (DOE-HDBK-1140-2001). Washington, DC: U.S. Department of Energy.

Department of Transportation (2009). Alarms and alarms in the technical operations environment. HF-STD-003. Federal Aviation Administration.

Duncanson, J. (1994). Visual and auditory symbols: A literature review (DOT/FAA/CT-TN94/37). Atlantic City International Airport, NJ: Federal Aviation Administration, William J. Hughes Technical Center.

Electric Power Research Institute. (1988). Effective plant labeling and coding (EPRI NP 6209). Palo Alto, CA: Research Reports Center.

Federal Aviation Administration. (2007). General maintenance handbook for National Airspace System (NAS) facilities (FAA Order 6000.15E). Washington, DC: Federal Aviation Administration.

Federal Aviation Administration. (2007). General maintenance handbook for National Airspace System (NAS) facilities (FAA Order 6000.15E). Washington, DC: Federal Aviation Administration.

General Services Administration. (2000). Section 508 of the Rehabilitation Act of 1973: Electronic and Information Technology Accessibility Standards. Washington, DC: Office of Technical and Information Services.

Guillaume, A., Drake, C., Rivenez, M., Pellieux, L., & Chastres, V. (2002). Perception of urgency and alarm design. Proceedings of the 8th International Conference on Auditory Display (pp. 357-361). Kyoto, Japan.

Haas, E. C., & Casali, J. G. (1993). The perceived urgency and detection time of multi-tone and frequency-modulated warning signals. Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting.

Haas, E., & Edworthy, J. (1996). Measuring perceived urgency to create safe auditory warnings. Human factors perspectives on warnings, 2, 90-94.

Haas, E., & Edworthy, J. (1996). Measuring perceived urgency to create safe auditory warnings. Human factors perspectives on warnings, 2, 90-94.

Hellier, E. J., Edworthy, J., & Dennis, I. (1993). Perceived urgency of an response to multi-tone and frequency modulated warning signals in broadband noise. Ergonomics, 38, 2313-2326.

International Organization for Standardization. (1996). Ergonomics – System of auditory and visual danger and information signs (ISO 11429). Geneva, Switzerland: International Organization for Standardization.

International Organization for Standardization. (1996). Ergonomics – Visual danger signals – General requirements, design, and testing (ISO 11428). Geneva, Switzerland: International Organization for Standardization.

International Organization for Standardization. (2003). Ergonomics – Danger signals for public and work areas – Auditory danger signals (ISO 7731). Geneva, Switzerland: International Organization for Standardization.

Kanis, H. (1993). Operation of controls on consumer products by physically impaired users. Human Factors, 35, 305-328.

Laughery, K., Wogalter, M., & Young, S. (Eds.). (1994). Human factors perspectives on warnings. Santa Monica, CA: Human Factors and Ergonomics Society.

Merideth, C., & Edworthy, J. (1994). Sources of confusion in intensive therapy unit alarms. In N. Stanton (Ed.), Human Factors in alarm design (pp. 208-219). London: Taylor & Francis Ltd.

Microsoft Corporation. (1992). The Windows interface – An application design guide. Redmond, WA: Microsoft Press.

National Aeronautics and Space Administration. (1995). Man-systems integration standards (NASA-STD-3000B). Houston, TX: National Aeronautics and Space Administration.

National Air Traffic Services. (1999). Human factors guidelines database. Christchurch, UK: National Air Traffic Services, Human Factors Unit.

O'Hara, J., Brown, W., Lewis, P., & Persensky, J. (2002). Human-system interface design review guidelines (NUREG-0700, Revision 2). Washington, DC: U.S. Nuclear Regulatory Commission.

Patterson, R. D. (1982). Guidelines for auditory warning systems on civil aircraft. CAA paper 82017. London: Civil Aviation Authority.

Sanders, M. S., & McCormick, E. J. (1993). Human factors engineering and design. New York: McGraw-Hill.

Seminara, J. (1965). How to apply human factors principles to warning system design. Machine Design, 37, 106-116.

Smith, S. L., & Mosier, J. N. (1986). Guidelines for designing user interface software (ESD-TR-86-278). Hanscom AFB, MA: Electronic Systems Division.

Stanton, N. (1994). Human factors in alarm design. London: Taylor & Francis.

Stanton, N., & Edworthy, J. (1994). Towards a methodology for constructing and evaluating representational auditory alarm displays. Contemporary Ergonomics, 360-365.

Stephan, K., Smith, S., Martin, R., Parker, S., & McAnally, K. (2006). Learning and retention of associates between auditory icons and denotative referents: Implications for the design of auditory warnings. Human Factors, 48(2), 288-299.

Van Orden, K. F., DiVita, J., & Shim, M. J. (1993). Redundant use of luminance and flashing with shape and color as highlighting codes in symbolic displays. Human Factors, 35(2), 195-204.

Vanderheiden, G.C., & Vanderheiden, K.R. (1991). Accessible design of consumer products: Guidelines for the design of consumer products to increase their accessibility to people with disabilities or who are aging. Madison, WI: Trace Research and Development Center.

Wiener, E. L. (1988). Cockpit automation. In E. Wiener & D. C. Nagel (Eds.), Human Factors in Aviation San Diego, CA. Academic Press.

Wiener, E. L., & Curry, R. E. (1980). Flight-deck automation promises and problems. Ergonomics, 23, 995-1011.

Wogalter, M., Young, S., & Laughery, K. (Eds.). (2001). Human factors perspectives on warnings: Vol. 2. Santa Monica, CA: Human Factors and Ergonomics Society.

Appendix C. Index